3.2 The Icy Epoch

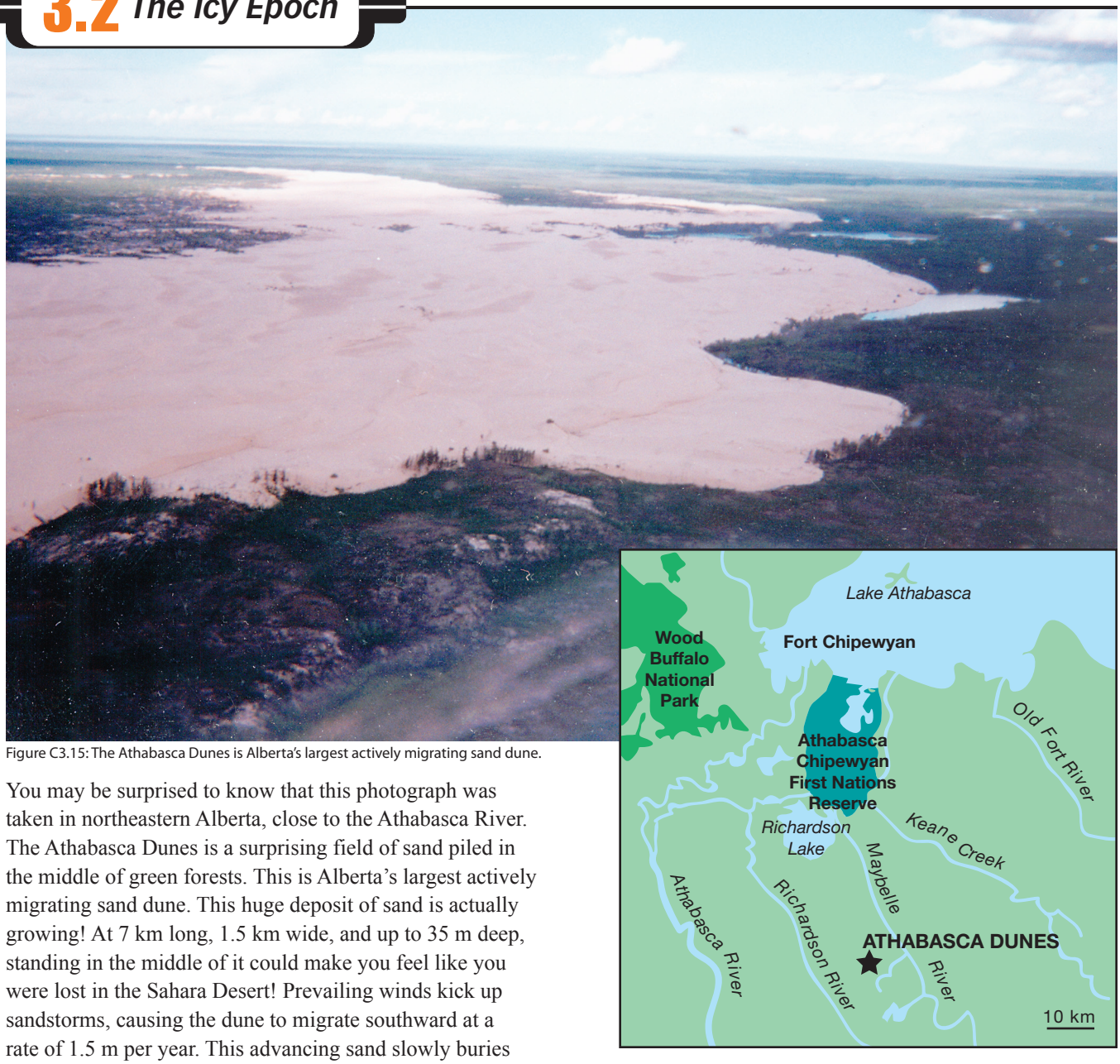

Figure C3.15: The Athabasca Dunes is Alberta's largest actively migrating sand dune.

You may be surprised to know that this photograph was taken in northeastern Alberta, close to the Athabasca River. The Athabasca Dunes is a surprising field of sand piled in the middle of green forests. This is Alberta's largest actively migrating sand dune. This huge deposit of sand is actually growing! At 7 km long, 1.5 km wide, and up to 35 m deep, standing in the middle of it could make you feel like you were lost in the Sahara Desert! Prevailing winds kick up sandstorms, causing the dune to migrate southward at a rate of 1.5 m per year. This advancing sand slowly buries everything in its path, including trees, ponds, streams, and lakes. A seemingly lifeless desert is left behind.

What process could have created this strange and rare environment? Where did all that sand come from? The answer is surprising: Ice! A sheet of ice more than 1 km thick flowed across Canada and buried nearly everything in its path. In fact, over the last 1.7 million years, moving ice has shaped Alberta's landscape more than anything else. Ironically, this wall of advancing sand mimics the ice sheet that created it more than 18 000 years ago.

1.7 million years ago: glaciers begin to advance on Alberta

The Big Freeze

As you learned earlier in this chapter, a cooling trend that began in the Cretaceous Period continued throughout the Tertiary Period. By the end of the Tertiary Period—1.7 million years ago—the climate became so cold that snow began to accumulate year after year in polar regions. This marked the beginning of the icy Pleistocene Epoch (from 1.7 million years ago to 10 000 years ago).

During the early Pleistocene Epoch, as layer upon layer of snow fell in polar regions, the weight caused lower layers of snow to become compacted into ice, which began the formation of **glaciers**.

glacier: a large river of ice that forms on land and moves under the influence of gravity

Earth's largest glaciers can be found in the polar regions—the Greenland and Antarctic continental ice sheets. During the Pleistocene Epoch, when ice sheets like these reached a critical mass, they began to slowly flow outward toward the equator like a viscous fluid.

- continental ice sheet: a very large glacier, often more than 1 km in depth, that forms in polar regions
- mountain glacier: a glacier that forms in mountainous regions at high elevations

Figure C3.16: The continental ice sheet covers most of Greenland.

Figure C3.17: Weather stations are scattered throughout Greenland's continental ice sheet.

Earth's current massive continental ice sheets cover nearly all of Antarctica and Greenland. Ice accumulates at their centres to depths of over two kilometres, then flows outward, eventually reaching the sea. Huge chunks of ice break off and float away as icebergs in a process called calving—as if the ice sheet were giving birth.

During the Pleistocene Epoch, snow also accumulated in mountainous regions and resulted in **mountain glaciers**. These glaciers reached a critical mass and began to form in the mountains and stretched into the valleys below.

Figure C3.18: An iceberg is born through the calving process on the coast of Greenland.

Moving ice continues to shape the face of Alberta to this day. If you take a drive through the Rocky Mountains, you can see masses of ice high on mountains. Although they are moving very slowly, these mountain glaciers are scraping and gouging the rock below them, giving the Rockies their characteristic jagged shape.

Utilizing Technology

Antarctica: A Flying Tour of the Frozen Continent

Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

To really get a feel for what the Antarctic Ice Sheet is like, watch the narrated animation applet of a flyby over Antarctica. The applet titled "Antarctica: A Flying Tour of the Frozen Continent" can be found on the Science 20 Textbook CD. This animation was generated using a computer program to "drape" satellite radar images over a digital topographical map. The data was collected by the Canadian Space Agency's satellite, RADARSAT-1.

Analysis

1. This satellite's ability to map the distribution of sea ice is particularly valuable to Canada because of the proximity of many Canadian ports to the North Pole. This allows for the planning of safe shipping routes and the monitoring of large iceberg flows. Concisely explain how this satellite, designed to monitor ice around the North Pole, was able to capture radar images of the Antarctic Continental Ice Sheet.
2. Many students are surprised to learn not only that Canada has a thriving aerospace industry but also that Canada is a world leader in satellite technology.
   a. Why is satellite technology particularly important to a country like Canada?
   b. Internet Search: You can learn more about the Canadian aerospace industry, take virtual tours of facilities, and view the latest images from Canadian satellites by visiting the Canadian Space Agency's website. Use your search engine to locate this site and then follow the links. Concisely record some interesting things you learned.

Are We in an Ice Age Right Now?

It depends on which definition you're using. An **ice age** is technically defined as a period when ice sheets cover parts of the Northern and Southern Hemispheres. Under this definition, Earth is in an ice age right now! Enormous ice sheets cover Antarctica in the south and Greenland in the north. Usually what people mean when they say *ice age* is a time period during which continental ice sheets advance to cover large regions of North America and northern Europe. These periods are more correctly called **glaciations**. Scientists believe that during the Pleistocene Epoch, there were at least four major glaciations.

- ice age: a period during which ice sheets cover parts of the Northern and Southern Hemispheres
- glaciation: a period during which polar ice sheets advance to cover large regions of North America and northern Europe

Giants of the Pleistocene

During the chilly Pleistocene Epoch, large mammals had the advantage. Fossils that were collected near Medicine Hat, Alberta, and in Walsh Valley, Saskatchewan, reveal that mammoths, modern horses, llamas, reindeer, camels, and scavenger dogs roamed the Pleistocene landscape. Vicious predators, such as American lions, short-faced bears, sabre-toothed cats, and birds with 8-metre wingspans, stalked herds of these large, grazing mammals. Some of the more exotic of these Pleistocene giants included woolly mammoths and woolly rhinoceroses.

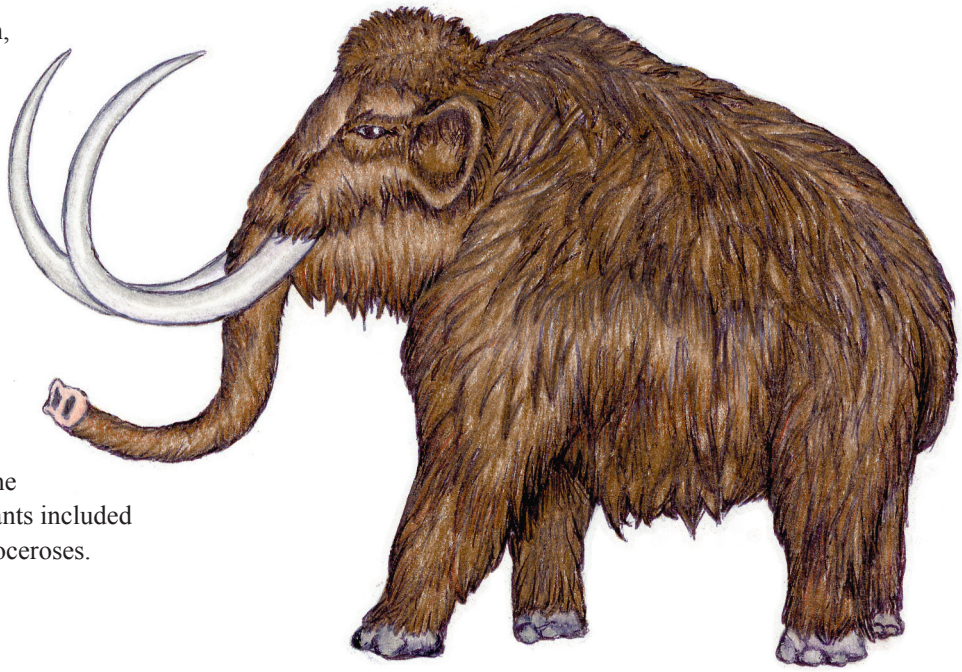

Figure C3.19: Woolly mammoths thrived during the Pleistocene Epoch.

Investigation

A Record in the Ice

Problem

Can ice-core data be used to show climatic changes over the past 160 000 years?

Background

In 1998, a Russian research team travelled to Lake Vostok, a salty glacial lake buried under thousands of metres of Antarctic ice. They made this difficult journey to study changes in Earth's past climate.

Figure C3.20: Two scientists make a small drill core in the Canadian Arctic to study previous atmospheric conditions.

They drilled to extract an ice core that was 2083 m long. Once they had removed the drill core, they analyzed tiny bubbles of the ancient atmosphere trapped in the annual ice layers. The researchers measured concentrations of carbon dioxide, methane, and dust particles and determined the average temperature at the time each layer formed by using oxygen-18: oxygen-16 ratios.

Figure C3.21: A scientist prepares to analyze a section of a drill core from a storage bank.

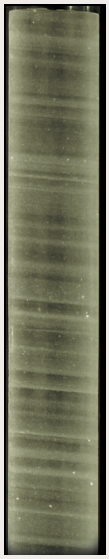

Figure C3.22: Annual snowfall layers are visible in ice cores.

Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

Using these measurements, scientists have constructed a chronological record of Earth's atmosphere for the last 420 000 years! Good scientific practice involves sharing your data with other scientists from around the world. This encourages an open exchange of information that promotes a confirmation of results and the development of consensus among scientists. During this investigation, you will analyze raw data from the Vostok Ice Core by using the power of a computer spreadsheet program.

Collecting the Data

Open "Vostok Spreadsheet and Data" on the Science 20 Textbook CD, and save it on your computer.

Procedure

Notice that the Average Temperature column in the spreadsheet is empty. You will need to complete this column using the data provided. A proportional relationship has been established for oxygen-18 in ice formed recently in areas around the world. From this relationship, an equation has been developed for you to use.

step 1: Select cell B3 and enter the following equation:

$= -55.5 + (C3 + 440)/6$

This equation is based on the linear relationship between oxygen-18 ratios and average temperature.

step 2: Press Enter.

step 3: Select cell B3 again. Click on the lower right corner of the cell and, while holding down the mouse button, drag the cursor to the bottom of the column. This should apply the formula for average temperature to each line in the column.

Now, you can graph the average temperature over the past 160 000 years.

step 4: Select the Age of Ice Layer and the Average Temperature column (cells A2 to B196).

step 5: Open the Chart Wizard.

step 6: Choose XY (Scatter). Also, choose the sub-type with the data points connected by smoothed lines without markers.

step 7: Click the Next button.

step 8: Preview the graph; then click the Next button.

step 9: Format your graph by adding graph and axes titles, gridlines, and so on. Simply review the formatting under each tab in this window.

step 10: Click the Next button.

step 11: Select the radial button that will save the graph on a different sheet. Title the sheet "Graph."

step 12: Click the Finish button. Your graph will appear on a new sheet in the spreadsheet file.

Note: You can do additional formatting to the graph by simply double-clicking the area you wish to change, such as the background or the scale of each axis.

Save your spreadsheet. You will be referring to it later in this chapter.

Conclusion

1. List the advantages and disadvantages of using a spreadsheet to analyze data compared to using a pencil and paper.
2. Describe the relationship between time and the average temperature at Vostok over the past 160 000 years, as shown by the graph you created.
3. These days, the average temperature in Vostok is a chilly -55.1°C. Draw a dashed line across your graph and label it "current temperature."
4. According to the graph, how many time periods were there in Vostok during the last 160 000 years when the average temperature consistently stayed above the current temperature?
5. The cold periods indicate the last two glaciations (commonly called ice ages). Use the graph to answer the following.
   a. When did the most recent major cooling trend begin that led to glaciation?
   b. When did the last glaciation reach its maximum (e.g., coldest) temperature?
   c. When did the temperature finally return to near-current values?
6. What significance does the end of the last glaciation have in terms of the Geological Time Scale?
7. Based on your graph, infer one of the following predictions. The temperature over the next 10 000 years will do one of these things.
   A: stay roughly constant for the next 10 000 years
   B: undergo another decrease
   C: increase
8. Explain why it is important for scientists around the world to share data and conclusions with each other.

The Wisconsin Glaciation

The last glaciation is often called the Wisconsin Glaciation to indicate how far south the ice advanced before it stopped. The Wisconsin Glaciation reached its maximum size approximately 18 000 years ago. The largest of the advancing ice sheets was the Laurentide Ice Sheet. This ice originated just west of where Hudson Bay is now, and it spread out in all directions. This wall of advancing ice entered Alberta from the northeast and continued to spread down through the province until it was deflected south by mountain glaciers. The mountain glaciers were moving east as they came down the mountains. The Laurentide Ice Sheet made it all the way to northern Montana before it stopped advancing and started to melt. The Laurentide Ice Sheet fully receded approximately 10 000 years ago to mark the end of the Pleistocene Epoch and the beginning of the Holocene Epoch.

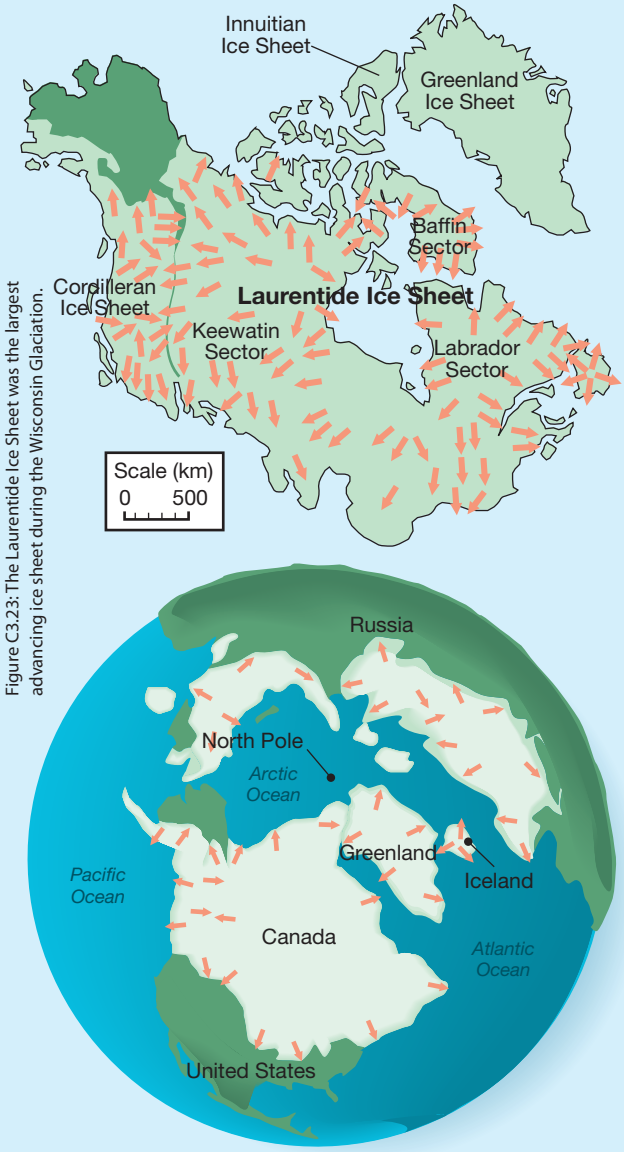

Figure C3.23: The Laurentide Ice Sheet was the largest advancing ice sheet during the Wisconsin Glaciation.

Glacial Footprints

If Alberta were indeed covered by a giant ice sheet, it must have left behind a lot of evidence. It did leave proof. In fact, Alberta's topography is dominated by the effects of the Wisconsin Glaciation. As a continental ice sheet advances and then retreats, it leaves behind characteristic landforms, as shown in Figures C3.24, C3.25, and C3.26.

Figure C3.24: This strangely shaped hill, called a drumlin, is one of a cluster of teardrop-shaped hills found at Morley Flats west of Cochrane, Alberta. Geologists believe the glacier that flowed over these hills travelled from the blunt end toward the tapered end.

Figure C3.25: Between the towns of Slave Lake and Fort Vermilion in northern Alberta, there are many small round hills, called kames, and scattered ponds. These small hills, many of them shaped like doughnuts, are collections of rocky debris that were slowly dropped by a glacier chunk thought to have been stranded from the larger ice mass. Since these glaciers were stalled and left to melt in place, these deposits lack the streamlined effect of Figure C3.24.

Figure C3.26: The Athabasca Dunes, featured in the Lesson 3.2 introduction, is a giant pile of sand deposited by water. This sand dune is glacial lake sediment. The origin of the sand is granite, gneiss, and sandstone located in the Canadian Shield area of northeastern Alberta. The advancing ice sheet plucked up enormous amounts of fine, clean sand as it scraped and gouged its way across these rocks. When the ice sheet melted, sandy water poured into a glacial lake. Later, the lake drained and left this huge deposit of sand.

Practice

5. Identify the event that marked the end of the Pleistocene Epoch and the beginning of the Holocene Epoch.
6. Identify three examples of landforms that provide evidence of glaciation in Alberta's past.

Mountain Make-Over

What gives the Rocky Mountains their characteristic jagged shape? The Rockies started out more rounded in shape, except for V-shaped valleys formed by water erosion. The jagged shapes that inspired the name Rocky Mountains came from the glaciers of the Pleistocene Epoch. During the Wisconsin Glaciation, as in previous glaciations, the mountains were covered with glaciers. There are still many places in the Rockies where the winter snowfall exceeds the summer melting. Under the influence of gravity, the accumulating snow is compacted to become ice. At a critical mass, the ice begins to flow like a very slow river down the mountain and into the valleys below.

As the mountain glacier flows, it scrapes and gouges the mountain. This drastically changes the mountain's appearance. Once the ice reaches a lower elevation, where it gets warmer in the summer, the ice melts. The melted ice is replaced by ice flowing down from the zone of accumulation. Fresh meltwater from the zone of ablation runs into streams, which converge to form rivers. If you live in Alberta, chances are good that the water coming out of your tap is glacial meltwater.

Investigation

Fresh Water

Glaciers hold 75% of Earth's fresh water. When water freezes, it forces out dissolved salt. So, when ice melts, it is usable as drinking water by plants and animals, including humans. Many scientists are interested in monitoring this vast resource and projecting changes in Earth's future ice volume. Use the Internet or other sources to conduct research on this issue. Use questions 1 to 8 to guide your research. Include diagrams and/or pictures to illustrate your answers. A good place to start your research is by finding the website of your local drinking-water utility.

Science Skills

- ✓ Performing and Recording
- ✓ Analyzing and Interpreting

Questions

1. Where does your drinking water come from? Is it a river? If so, which one?
2. Is the river that supplies your drinking water fed by a glacier? If so, which one?
3. Over the past century or so, has that glacier been growing or shrinking?
4. Are mountain glaciers and ice sheets around the world growing or shrinking? Provide evidence.
5. What methods do scientists use to measure changes in glacier size?
6. Why do many scientists believe the last century is just the beginning of a large glacial melt?
7. What could the consequences be if the glacier that supplies your drinking water melts completely?
8. What could some consequences be if most of Earth's glaciers and ice sheets melt?

3.2 Summary

The Tertiary Period experienced a drastic cooling trend, which continued into the Quaternary Period. The coldest times came during the first epoch of the Quaternary Period—the Pleistocene. Glacial landforms and ice-core data show evidence of repeated glaciations starting 1.7 million years ago and lasting until the end of the most recent glaciation (known as the Wisconsin Glaciation) 10 000 years ago. Ice continues to shape the world to this day as enormous ice sheets dominate Antarctica and Greenland and mountain glaciers continue their slow grinding in Alberta's Rocky Mountains. The many retreating glaciers and ice sheets around the world may be indicators of a warming trend in recent years, which could lead to challenges in the future, such as rising sea levels and fresh water shortages.

3.2 Questions

Knowledge

1. Define the following terms. Include times and major events.

- **a.** the Quaternary Period
- **b.** the Pleistocene Epoch
- **c.** the Holocene Epoch

2. What percentage of the Quaternary Period is taken up by the Pleistocene Epoch?

3. Describe Earth's climate during the Pleistocene Epoch.

4. Describe the animals that lived in Alberta during the Pleistocene Epoch.

5. Define the following terms, describe how they form, and give one example of each term.

- **a.** continental ice sheet
- **b.** mountain glacier

6. Explain how ice cores are used to study Earth's past climate.

7. Describe how Earth's average temperature has changed over the past 160 000 years.

8. Compare and contrast the two main methods of tracking Earth's average temperature from the distant past—deep-ocean sediment cores versus ice cores.

9. Explain how, over the past century, glaciers have provided evidence of the effects of global warming.

Applying Concepts

10. Figure C3.27 shows a photo of a glacial landform.

- **a.** Explain how it formed.
- **b.** Sketch a quick drawing of this landform. Use an arrow to indicate the direction of ice-sheet flow.

Figure C3.27: This is an example of a glacial landform.

11. Figure C3.28 shows a photo of a glacial landform. Explain how this highlighted feature formed.

Figure C3.28: This large bowl was carved out by a glacier.